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EVALUATION OF MANILA-ROPE FIBER FOR COLOR

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ABSTRACT

A quantitative method for the evaluation of the color of manila-rope fiber was developed at the request of the Cordage Institute and the Cordage Committee of the Federal Specifications Board. Spectral reflection and colorimetric measurements showed that the variations in color correspond chiefly to variations in luminous reflectance. The reflectance at wave length 500 mμ, which is obtainable with relatively simple apparatus, was found to be sufficient for the grading of the fiber for color. The fibers in a cross section of the rope are cut into lengths of 1.5 to 2.5 mm, mixed, extracted with petroleum ether, and spread out to give a smooth surface. The ratio of the reflectance of this surface to that of the usual white standard magnesium oxide surface for light of wave length 500 mμ (when the two surfaces are in effect equally illuminated at an angle of approximately 45° and viewed in a line approximately perpendicular to the surfaces) multiplied by 100 gives the numerical value, "Becker value", for the rope. The Becker value of the commercial ropes tested varied from 29.0 to 51.0. Before removal of the lubricant the values were from 8 to 16 units lower. The value obtained for a single specimen taken from a coil of rope was found to be within two units of the average value for several specimens. The method is prescribed in the latest revision of the Federal specification for manila rope.

CONTENTS

I. INTRODUCTION

Manila rope is used extensively throughout the United States in private activities. The military, naval, and engineering establishments of the United States Government require considerable quantities of manila rope in their regular work. Human safety frequently depends upon the quality of the rope.

The official Philippine Island government grading of abacá fiber from which manila rope is made is based upon three characteristics: strength, "cleaning", and color.[3] In general, the greater the strength of the fiber the stronger the rope made from it and the cleaner the fiber the more resistant the rope to decay.[4] The different grades vary in color from light straw to dark brownish or purplish.

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[3] Fiber Standardization Board administrative order no. 7. Determination and Description of the Official Standards for the Various Commercial Grades of Certain Philippine Fibers. 16 pp. 1932. Department of Agriculture and Natural Resources, Manila, P.I.
[4] M. M. Saleeby: The Standard Grades of Abacá, Their Causes, Origin, and Influence on Production. Bulletin no. 1, Fiber Standardization Board, Manila 1930.

The Federal Specification for Manila Rope used from 1929 to 1933 [5] prescribed the grades and the proportions of these grades to be used in rope for Government purchase. In view of the impracticability of inspection of the fiber going into rope for Government contracts and the impossibility of determining the grades of fiber by visual examination of the finished rope, the Cordage Institute and the Cordage Committee of the Federal Specifications Board joined in a request that the Bureau of Standards develop a method for the evaluation of the color of the fiber in rope, for use as a measure of the grade of the fiber. The intention was to prescribe this method in a revision of the Federal specification. It was also anticipated that the method would prove to be of value to the industry in the standardization of its product.

This paper is one outcome of the request. It discusses the preparation of specimens of the fiber for color measurement, reports the results of spectrophotometric and colorimetric measurements of the fiber in ropes of different grades, and describes a relatively simple method for evaluating one element of the color which appears adequate for the purpose. The effects of the lubricant in rope and its removal on the color of the fiber are shown. Methods of sampling are discussed and the reproducibility of results is indicated.

This work was not concerned with the relation between the color of fiber and the serviceability of rope made from it. The serviceability of rope obviously depends upon its strength and its resistance to deterioration influences such as light, heat, wetting and drying, organisms, repeated flexing, loading and unloading. Although the opinion has been held in the industry that rope made from dark grades of fiber is less serviceable than that made from lighter grades, recent experiments carried out by the Navy Department indicate that some darker rope may be as serviceable as the Navy standard. It should be remembered that abacá fiber may be bleached, though current practice is not to bleach it.

The proposed method has been incorporated in the latest revision of the Federal specification [6] and is being used by a number of cordage manufacturers.

The work reported here was made possible by the establishment of a research associate at the Bureau of Standards by the Cordage Institute, J. S. McDaniel, secretary, and was greatly facilitated by the generous cooperation of 12 cordage manufacturers and the Boston Navy Yard in furnishing the rope required for experiments. Dr. K. S. Gibson and Dr. Deane B. Judd of the colorimetry section of the Bureau of Standards have made numerous valuable suggestions in the course of the work. Their help is gratefully acknowledged.

II. PREPARATION OF SPECIMEN

Several methods for preparing the rope fiber for measurement were considered. It is possible to measure the average color of a section of the rope, coiled in such a way as to give a measurable surface, or of short lengths of rope laid side by side, or even of a small area on the rope. However, the results obtained would depend upon the construction of the rope, the yarn size, number of strands, and amount of twist. Further, any dirt or dust on the rope would materially alter

[5] F.S. No. 61b, Rope, Manila, 5 p. 1929. U.S. Government Printing Office, Washington, D.C.
[6] F.S. No. T-R-601, Rope, Manila, 8 p. Mar. 7, 1933. U.S. Government Printing Office, Washington, D.C.

the results. This would be the method to use if the color of the surface of the rope itself were to be measured, but the color of the fiber, rather than the color of the rope, is of primary interest.

A second method for preparing the rope would be to untwist the yarns and lay the fibers out in a mat. This did not prove satisfactory unless the fibers were soaked in water to remove the twist from them. Even then, a flat, smooth, readily duplicable surface was not obtained.

A third method is to cut the fibers into short lengths. This proved to be satisfactory and was the method adopted. The colored marker is removed from a short piece of rope and sections from 1.5 to 2.5 mm long are cut at right angles to the long axis of the rope by means of a rotating disk meat cutter. The fibers thus obtained are mixed and bottled.

This specimen is representative of all of the fibers in the cross section of the rope. A minimum of rope is required since 8 g of the cut fiber is a sufficient quantity for measurement.

A portion of the fiber is placed in a dull-black receptacle at least 4 mm deep. By using the proper quantity of fiber and smoothing the surface with a spatula, the receptacle is filled and a surface effectively uniform and reproducible is obtained.

Spectral reflectance measurements of different surfaces prepared from the same lot of fiber were found to be in good agreement. (See fig. 1 and the next section of this paper.) Doubling the thickness of the layer of fiber measured did not change the values obtained. A glass cover placed over the fiber to prevent disturbance of the sample during measurement was tried, but it was found to be unnecessary if reasonable care were used to avoid jarring the specimen during measurement.

Special attention was given to the effect of variation in the length of the fibers. Distinctly lower values for the spectral reflectance were obtained with fibers cut to lengths of 5 to 6 mm. The long fibers gave a less satisfactory surface, but the short fibers required a longer time and much more care in cutting. Lengths of 1.5 to 2.5 mm were found to be reasonable satisfactory from all points of view and are prescribed for the standard procedure.

III. SPECTROPHOTOMETRIC STUDIES

Curves showing the spectral reflectance of specimens of fiber from very light, medium, and very dark 1-inch manila ropes are given in figure 1. The specimens were prepared by the method already outlined. They were not extracted to remove lubricant as provided for in the final method. The reflectance of the specimen relative to that of a standard white magnesium oxide (MgO) surface [7] is plotted as a function of the wave length of light. Fresh surfaces from the same specimens of fiber were prepared and measured at several different times. The results of each series of measurements are represented in figure 1 by circles of the same size. The curves are drawn on the basis of all of the data except those represented by the largest circles, to be referred to later. The Koenig-Martens spectrophotometer [8]

[7] Directions for the preparation of this surface are obtainable from the colorimetry section, Bureau of Standards. According to the International Critical Tables, vol. 7, p. 262, the ratio of total reflected to total incident light from MgO is 97 percent. Preston (Trans. Optical Soc. (London), vol. 31, p. 26, 1929–30) gives the "total factor under diffused light" as 0.974. The selectivity of MgO has been found to be negligible by Priest (J. Optical Soc. Am., vol. 20, p. 156, April 1930).

[8] H. J. McNicholas. Equipment for Routine Spectral Transmission and Reflection Measurements. B.S. Jour. Research, vol. 1 (R.P. 30), p. 793. November 1928.

was used. The illumination of specimen and standard was effectively equal and completely diffused and the direction in which the reflectance was measured was perpendicular to the plane of the surfaces of specimen and standard. The results were furnished by the colorimetry section of the Bureau.[9]

The reproducibility of the surface of the specimen with respect to its reflectance is shown by the agreement in the results of the several series of measurements represented in figure 1.

The results of a single series of observations on the same specimens using the Martens photometer and auxiliary equipment in the textile section of the Bureau[10] are indicated in figure 1 by the largest circles. They represent the reflectance relative to magnesium oxide at seven

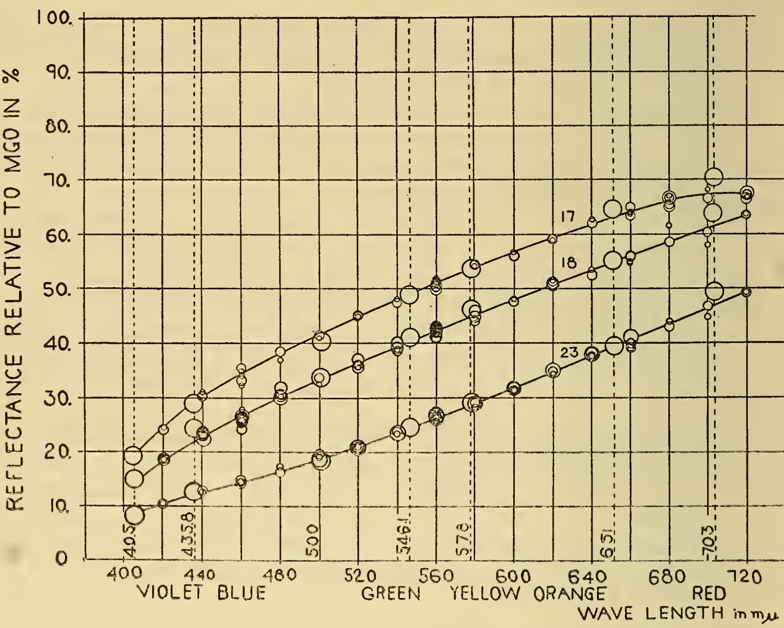

Figure 1.—*Spectral reflectance of fiber from manila rope.*

No. 17 was the lightest 1-inch rope tested, no. 23 the darkest, and no. 18 was intermediate in color. Fresh surfaces from the same specimens of fiber were prepared and measured at several different times. The results of each series of measurements are represented by circles of the same size. All circles except the largest represent measurements made by the colorimetry section with the Koenig-Martens spectrophotometer, using diffuse illumination. The largest circles represent measurements using the Martens photometer equipment and 45° illumination.

wave lengths when specimen and standard white are in effect equally illuminated at an angle of approximately 45° and the line of sight is approximately perpendicular to the surfaces.

In general, the data obtained with the relatively simple Martens photometer equipment are in good agreement with those from the colorimetry section even though the illumination was a directed beam at 45° instead of being completely diffused. The curves show that the reflectance of the rope fiber does not change rapidly with changes in wave length in the visible spectrum. For these reasons, the measurements at the seven wave lengths were considered satisfactory for

[9] Unpublished report. B.S. Test no. 431a-43. Mar. 25, 1932.
[10] Wm. D. Appel, A Method for Measuring the Color of Textiles. Am. Dyestuff Reptr., vol. 17, p. 49, Jan. 23, 1928.

a study of the variations in spectral reflectance of fiber from commercial ropes.

The results of measurements made with the Martens photometer equipment on the fiber from twenty-five 1-inch manila ropes, prepared as previously described but not extracted, are shown in figure 2. The ropes are the products of 13 manufacturers and include the several grades recognized by the industry. It will be noticed that the curves are of the same general shape. Similar results were obtained for the fibers from ropes of other sizes.

These curves suggested that the reflectance of the specimen relative to that of a magnesium-oxide surface for light of a single wave length, say 500 mμ, might serve as a satisfactory measure of the grade of the rope fibers.

IV. SCALE FOR GRADING ROPE FIBER WITH RESPECT TO COLOR

The color of a rope-fiber specimen depends not only upon the spectral reflectance as represented in figures 1 and 2, but it also depends upon the character of the illuminant and the eye of the observer. Assuming a standard illuminant and a standard observer, it is possible to calculate from the spectral reflectance three numbers which will adequately specify the color.[11] Any one of several triads of numbers might be used for this specification. Those used here are: (1) The reflectance of the specimen relative to that of the standard white for 31 wave lengths in the visible spectrum weighted with respect to visibility, called here the "luminous reflectance"; (2) the value of the "red" coordinate [12]; and (3) the value of the "green" coordinate. The value of the "blue" coordinate is not essential to the representation of the color because it is related to the red and green coordinates according to the equation: blue = 1 − (red + green).

The specifications for the colors of the specimens whose spectral-reflectance curves are given in figure 1, were calculated by the method outlined in the Report of the Committee on Colorimetry, Optical Society of America, pages 580–581,[13] assuming the prime-basic stimulus to be Abbot-Priest sunlight and the eye to be that represented in the Optical Society of America "excitation" curves in their extrapolated form.[14] The results are given in table 1.

TABLE 1.—*Specifications* [a] *for the colors of specimens of fibers from light, intermediate, and dark manila rope*

Specimen no.	Luminous reflectance		Red coordinate		Green coordinate	
	A [1]	*B* [2]	*A*	*B*	*A*	*B*
17	0.503	0.501	0.399	0.404	0.363	0.364
18	.417	.425	.409	.406	.365	.364
23	.260	.260	.433	.432	.365	.365

[1] Data in columns A are calculated from measurements at 20 mμ intervals throughout the visible spectrum with the Koenig-Martens spectrophotometer and diffused illumination.
[2] Data in columns B are calculated from measuresments at 7 wave lengths obtained with the Martens photometer equipment and 45° illumination.

[a] All values are computed with Abbot-Priest Sunlight as prime-basic stimulus.

[11] The discussion of the broad subject of colorimetry is not within the scope of this paper. The following reference may prove helpful: Report of Committee on Colorimetry, L. T. Troland, chairman, J. Optical Soc. Am., vol. 6, p. 527, 1922.
[12] See p. 547–553 of the reference given in footnote 11. See Deane B. Judd, Chromaticity sensibility to stimulus differences. J. Optical Soc. Am., vol. 22, pp. 72–108, 1932, in which the red and green coordinates are used.
[13] See footnote 11, p. 814.
[14] Deane B. Judd, Reduction of Data on Mixture of Color Stimuli, B.S.Jour. Research vol. 4 (R.P. 163), pp. 524–525, table 1, April 1930.

Similar results calculated on the basis of the spectral reflectance at the seven wave lengths, represented by the large circles in figure 1, are also given in table 1.[15]

The agreement between the results obtained from the more nearly complete spectral reflectance data and from the seven wave lengths only, justify the use of data of the latter type for evaluating the colors of the rope fibers represented in figure 2.

The results obtained by several methods for the evaluation of the colors of the fibers of manila ropes are given in figure 3. The numbers of the specimens from the 25 ropes whose spectral reflectances are given in figure 2, are arranged at the bottom of figure 3, in the order of the appearance of the specimens, from light to dark. This

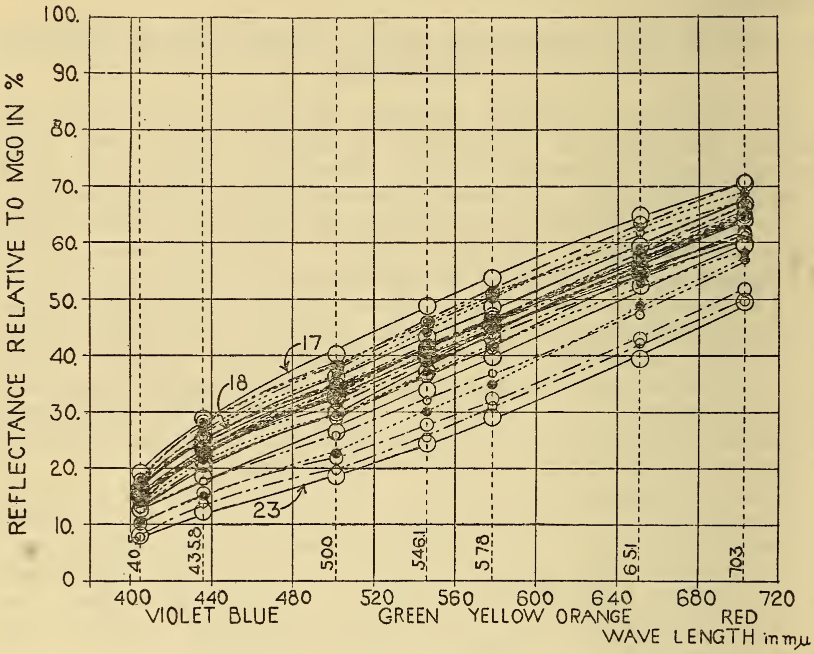

FIGURE 2.—*Spectral reflectance of fiber from 25 samples of 1-inch manila rope from 13 manufacturers*

Specimens numbers 17, 18, and 23, representing light, intermediate, and dark fiber, were also measured at every 20 millimicrons as shown in figure 1.

order is based upon the considered judgment of two observers who have had experience in judging colors. It should be noted that it was extremely difficult in some instances to decide which specimens were darker and which lighter among as many as 3 or 4 listed in order

[15] The "excitation" values used in this computation were derived by Dr. Deane B. Judd. Abbot-Priest sunlight is taken as the prime-basic stimulus. The Optical Society of America "excitation" curves in their extrapolated form are used as the basis for the derived "excitation" values. Judd states in his unpublished report to the textile section of the Bureau of Standards, dated Dec. 9, 1929: "If these values are used in the usual routine way for the computation of trilinear coordinates (r, g, b), and reflectance for the prime stimulus, the results will be exactly those found by computing on the basis of the O.S.A. "excitation" curves for an hypothetical sample whose reflection function in the neighborhood of the wavel engths specified is constant. The wave-length regions of constant spectral reflectance extend in each case half-way on the wave-length scale toward the next wave length specified. To what extent the trilinear coordinates of such a sample may be expected to differ from those of actual samples remains to be shown by actual trial. It is certain, however, that in such case as justify conclusions from spectral reflectances at these 7 wave lengths, the application of these "excitation" values will materially simplify the drawing and statement of the conclusions."

in the figure. The specimens were spread out side by side on a plane gray surface for visual comparison and were examined in north light, a pair at a time. The surface of each specimen viewed was about 1 by 2 centimeters in size.

The "luminous reflectance" and the "red" coordinates for the specimens calculated from the spectral reflectance at seven wave lengths are plotted in figure 3. The "green" coordinates of these 25 specimens show a maximum variation from 0.361 to 0.367, which is negligible. For this reason they were not plotted. The colors of the rope fibers vary from light to dark (measured by "luminous reflectance") and coincidentally they become slightly redder (measured by the "red" coordinate).

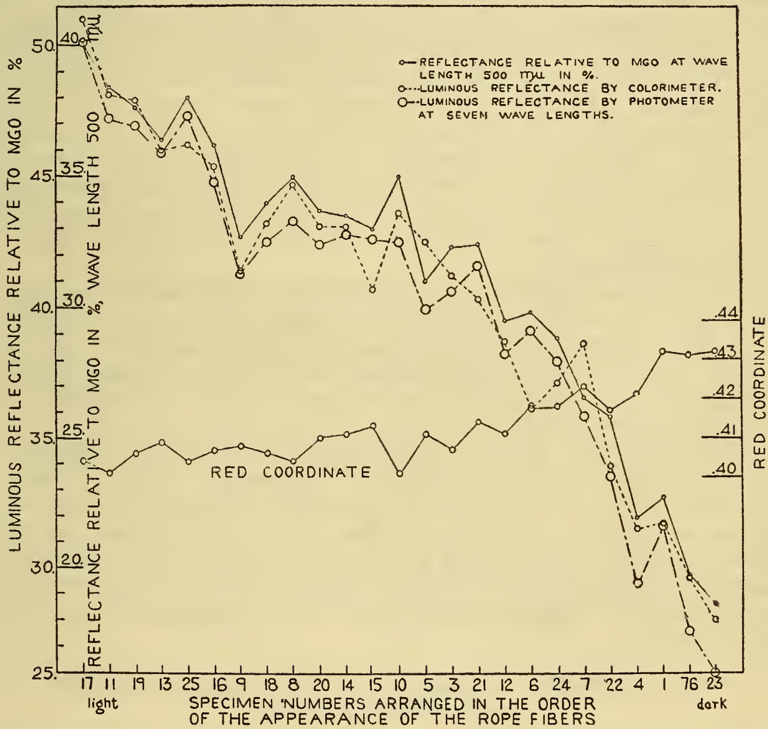

Figure 3.—*Comparison of several methods for the evaluation of the color of fibers from manila ropes*

The specifications of the colors can be readily obtained by the use of certain colorimeters as well as from the spectrophotometric data. Trial was made of the disk mixture colorimeter found by Nickerson [16] to be especially useful for grading raw cotton and other agricultural products. Munsell disks numbers YR 7/6, Y 8/8, N 8/, and N 3/ were used as standards.[17] The specifications of the colors were calculated from the spectral reflectances of the disks and the area of each

[16] Dorothy Nickerson, A Colorimeter for Use With Disk Mixture. J. Optical Soc. Am., vol. 21, p. 640, 1931; A Method for Determining the Color of Agricultural Products. U.S. Dept. Agr. Tech. Bull. no. 154, 32 pp., 1929; and Application of Color Measurement in the Grading of Agricultural Products. U.S. Dept. of Agr. Bur. Agr. Econ. Prelim. Rept. 36 pp. Mimeographed, January 1932.

[17] Munsell Book of Color 1929; and A. H. Munsell, A Color Notation. 1926, 7th ed. Munsell Color Co., Inc., Baltimore, Md.

disk required in rotary mixture to match the colors of the specimens. The values for "luminous reflectance by colorimeter", given in figure 3, were obtained in this way. The "red" and "green" coordinates obtained by the use of the colorimeter lead to the same conclusions as those obtained from the spectral-reflectance data, and consequently need not be reported.

The reflectance of each specimen relative to the reflectance of the white magnesium oxide surface at wave length approximately 500 mμ [18] (see fig. 2) is also plotted in figure 3.

It will be seen that the "luminous reflectance", "luminous reflectance by colorimeter", and "reflectance at wave length 500 mμ", for each specimen are reasonably consistent with one another and in a general way consistent with the order by visual inspection. The difficulty of arranging the specimens in a definite duplicable order has been pointed out. The fact that the order of the specimens obtained from visual inspection is not invariably obtained as a result of the measurements may be in part at least because of small differences in chromaticity which are confusing to the eye. It will be noted that where the "luminous reflectance" of a specimen is lower than that of adjacent specimens, the "red" coordinate of the color is in general higher than for adjacent specimens, but the "red" coordinate taken alone is notably less consistent with the visual order than the "luminous reflectance."

It is concluded that the most significant single entity for grading the color of manila rope fiber is "luminous reflectance", that the "red" and "green" coordinates may be ignored insofar as the range in color represented by ropes which have been examined are concerned, and that reflectance at wave length 500 mμ is as significant as the "luminous reflectance."

The measurement at wave length 500 mμ can be readily made with relatively simple and inexpensive equipment. The "luminous reflectance" cannot. The former appears to be as satisfactory for the purpose of grading manila rope fiber as more elaborate methods. Although, strictly speaking, it is not a measure of color, it does give a measure which is related to that characteristic of color which the results show to be the controlling element in the grading of manila rope fiber for color.

V. FACTORS AFFECTING THE RESULTS OF MEASUREMENTS

Most rope contains from 10 to 15 percent of an oil or other lubricant. This lubricant affects the color to various degrees depending upon the original color of the lubricant, the amount of dust it has picked up, and the extent to which it has been bleached or darkened through exposure to light and air. Since the proposed measurements are intended to show the color of the fiber before lubrication rather than as it actually occurs in rope, the cut fiber is extracted for 2 hours with petroleum ether in a Soxhlet extraction apparatus to remove the lubricant. In order to insure that the extraction does not remove colored materials

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[18] Measurements at approximately 500 mμ are conveniently obtained by illuminating the specimen and standard with light from a mazda C lamp operating near 2,848° K (the 300- or 500-watt lamps operating at normal voltage will be sufficiently close to this) and viewing them through Wratten filter no. 75 placed over the eyepiece of the photometer. (This filter is obtainable from the Eastman Kodak Co., Rochester, N.Y.) The filter isolates a relatively narrow spectral band. The exact wave length to assign to the measurement depends upon the color temperature of the incandescent lamp, the spectral transmission of the filter, and the visibility function of the observer.

other than the lubricant, the effect of the extraction upon fiber which had not been lubricated was studied. No significant change in reflectance at wave length 500 mμ resulted from the extraction.

TABLE 2.—*The effect of the lubricant and its extraction upon the reflectance of abacá fiber*

Sample no.	Material measured	Reflectance at wave length 500 mμ relative to MgO
		Percent
1	Original fiber	58.8
2	Original fiber+12 percent of its weight of oil (90 percent mineral oil+10 percent wool olein). Oil remained on fiber 9½ days	51.9
3	No. 2 extracted	57.0
4	Original fiber+12 percent of its weight of oil (75 percent mineral oil+25 percent degras). Oil remained on fiber 9½ days	51.0
5	No. 4 extracted	57.0

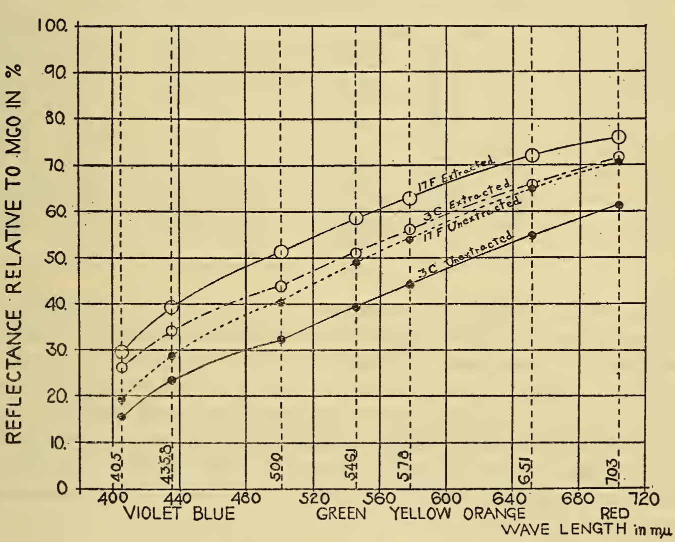

FIGURE 4.—*Spectral reflectance of fiber from manila ropes before and after extraction of lubricant.*

The results of experiments in which fiber of known reflectance was lubricated, measured, extracted, and again measured are given in table 2. The lubricants used decreased the reflectance considerably and the extraction did not completely restore the fiber to its original reflectance value. The extent to which the original value will be approached in any particular case will depend upon such factors as the susceptibility of the lubricant to oxidation or polymerization.

The extent to which extraction changes the spectral reflectance for typical rope fibers is shown in figure 4.

The reflectance at wave length 500 mμ of fiber specimens from 1-inch ropes before and after extraction are given in table 3. The order of decreasing reflectance is not exactly the same before and after extraction. The nominal grade of the ropes, as recognized in the trade,

is indicated in the table. In general, the lower grades have lower reflectance values.

Data similar to those in table 3 were otbained for a series of ½-inch and 5/16-inch manila ropes from the same manufacturers. The range in reflectance at 500 mμ for the twenty-five ½-inch ropes in the series before extraction was from 42.5 to 19.7 and for the twenty 5/16-inch ropes from 44.3 to 18.9.

TABLE 3.—*Reflectance at wave length 500 mμ of 25 samples of 1-inch manila rope from 13 different manufacturers. Results on both extracted and unextracted specimens are given*

Specimen no.	Nominal grade of rope	Reflectance at wave length 500 mμ relative to MgO		Specimen no.	Nominal grade of rope	Reflectance at wave length 500 mμ relative to MgO	
		Extracted	Unextracted			Extracted	Unextracted
		Percent	*Percent*			*Percent*	*Percent*
17	1	51.0	40.2	10	3	43.3	35.0
11	1	50.0	38.4	3	1	42.9	32.3
16	1	49.6	36.2	21	2	42.0	32.4
9	1	48.9	32.7	12	2	41.7	29.5
13	1	48.3	36.4	6	2	41.3	29.8
18	1	48.0	34.0	7	2	39.8	26.5
19	1	47.2	37.6	24	2	36.4	28.8
15	1	47.0	33.0	22	4	34.9	25.8
14	1	46.0	33.5	76	3	34.9	19.7
25	1	45.7	38.0	4	3	33.3	21.9
20	3	44.8	33.7	1	3	33.0	22.7
8	1	44.6	35.0	23	3	29.0	18.6
5	1	44.1	31.0				

In view of the effect of changes in atmospheric humidity on the properties of textile fibers, the effect on the reflectance of abacá fiber was studied. Specimens exposed to atmospheres having relative humidities ranging from nearly 0 to 100 were placed under the photometer in the ordinary room atmosphere and quickly measured. The results indicate that the variations in moisture content do not appreciably affect the values obtained under these conditions.

Numerous measurements were made to determine the duplicability of results for different surfaces prepared from the same specimens. The probable error in the value for a single surface is 0.8 percent of the average value for the surfaces.

The number of specimens to be taken from any coil [19] of rope in order to obtain a fair average reflectance value for the coil received attention. Half coils and portions from coils of first-grade 1-inch manila rope were used. In the study of the half coils, specimens for measurement were taken at equal intervals of the 600 feet of rope. In the study of the 60-foot lengths which were taken from the ends and center of each of the coils, specimens were taken at each end of these lengths. The reflectance values for specimens taken from five places in the half coils and from each end of the 60-foot lengths are given in table 4. The values given for the maximum variation in each of the lengths are the differences between the highest and lowest values obtained for the specimens in that length. Table 5 gives the average of the results for the 5 or 6 measurements on each coil and

[19] In commercial usage the standard length of a coil of 1-inch rope is 1,200 feet.

indicates how closely 3 measurements, 2 measurements, or a single measurement will approach the average value. If the average of the 5 or 6 measurements obtained for each coil is taken to be the true value for that coil then a single measurement would be well within 2 units of its true value.

TABLE 4.—*Values of reflectance at wave length 500 mμ for specimens taken at 3 to 6 places in a coil of rope*

Coil no.	Distance in feet from starting end of coil										Maximum variation
	0	60	150	300	450	570	600	630	1,140	1,200	
1	49.9	51.2	------	------	------	50.8	------	50.8	49.6	50.5	1.6
2	49.8	49.5	------	------	------	49.2	------	49.2	49.7	48.6	1.2
3	47.1	47.0	------	------	------	47.9	------	48.0	46.7	47.6	1.3
4	47.8	47.6	------	------	------	46.2	------	47.5	46.3	47.7	1.6
Half coil no.:											
1	44.7	------	44.1	44.5	45.5	------	44.5	------	------	------	1.4
2	44.7	------	45.8	46.8	44.5	------	45.3	------	------	------	2.3
3	44.4	------	46.3	47.2	46.7	------	44.8	------	------	------	2.8
Coil no.[1]:											
5	49.1	------	------	------	------	------	48.3	------	------	48.9	.8
6	45.0	------	------	------	------	------	45.1	------	------	46.8	1.8
7	40.3	------	------	------	------	------	39.5	------	------	39.0	1.3
8	53.8	------	------	------	------	------	53.2	------	------	51.6	2.2

[1] Samples from coils numbered 5, 6, 7, and 8 were furnished by 1 manufacturer and represent 4 qualities of rope.

TABLE 5.—*Summary of results indicating how nearly the average value for reflectance at wave length 500 mμ of a length of rope is approached by one or a few measurements*

	Coil number				Half coil number		
	1	2	3	4	1	2	3
Average of 5 or 6 measurements (equidistantly spaced throughout)	50.5	49.3	47.4	47.2	44.7	45.4	45.9
Average of 3 measurements (2 ends and center of length)	50.4	49.2	47.5	47.2	44.6	45.6	45.5
Average of 2 measurements (each end of length)	50.2	49.2	47.4	47.8	44.6	45.0	44.6
1 measurement—1 end	49.9	49.8	47.1	47.8	44.7	44.7	44.4
1 measurement—center	50.8	49.2	47.9	46.2	44.5	46.8	47.2

The sampling of rope at any considerable number of places would be costly both in rope wasted and the time and labor of the tests. There seems to be no more reason for taking a large number of samples for color than for taking a large number for breaking strength. Breaking strength is usually measured by testing a single specimen.

VI. STANDARD PROCEDURE

The procedure described here was proposed to the Cordage Committee of the Federal Specifications Board and has been incorporated in the latest revision of the Federal specification for manila rope.[20] The necessary equipment [21] can be assembled in any well-organized laboratory. At least one firm is prepared to supply equipment, specially built for the purpose.

[20] See footnote 6, p. 812.
[21] Working drawings of photometric equipment suitable for the purpose described and directions for its use are available on request to Textile Section, Bureau of Standards, Washington, D.C.

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All of the fibers in a representative cross section of the rope are taken for test. These fibers are cut into lengths of 1.5 to 2.5 mm. This may be done with scissors, tinner's snips, or a sharp knife, but more conveniently with a meat cutter having a revolving disk blade. The cut fibers are thoroughly mixed and an 8-g portion is extracted in a Soxhlet apparatus for 2 hours with petroleum ether. The extracted fibers are spread on a clean filter paper and allowed to dry in the air over night. The reflectance of the fiber is measured the following day.

The fiber is placed in a black receptacle not less than 4 mm deep and alternately pressed and smoothed with a spatula until a smooth, flat surface is obtained.

The ratio of the reflectance of this surface to that of the usual white standard magnesium oxide surface when the two are in effect equally illuminated at an angle of approximately 45° and viewed in a line approximately perpendicular to the surfaces is measured with a suitable photometer, at wave length approximately 500 mμ. This ratio multiplied by 100 is the reflectance of the fiber in percent relative to that of magnesium oxide. This value has been designated the "Becker value" in the Federal specification for manila rope.

WASHINGTON, September 16, 1933.